To study the different industrial applications of PLC through ladder diagrams .

A dissertation submitted
in partial fulfillment of the requirements for the award of the degree
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Abstract

PLC has evolved as an important controller in industries these days because of its simplicity and robustness. It is used for controlling many mechanical movements of the heavy machines or to control the voltage and frequency of the power supplies. In this project, study of the PLC has been done in great detail and also several industrial applications have been studied and realized through ladder diagrams. These ladder diagrams are simulated in either PLC trainer or PLC simulator software. Matlab /Simulink is also used for realizing physical situations as in case of dc motor and power inverter.

The applications on which we have stressed are the continuous bottle filling system, batch-mixing system, speed control of dc motor,3 stage air conditioning system, control of planar machine and the automatic frequency control of the supply, during induction heating .

Acknowledgement

First of all, I would like to express my gratitude and sincere thanks to my respected Faculty assistant Prof. T.K DAN for his professional guidance, advice, motivation , endurance and encouragements during his supervision period. The present work would have never been possible without his vital supports and valuable assistance.

Then I would like to thank all my friends whose tips and views were useful indeed and then thanks to the other faculty members and staff of the Department of Electronics and Communication Engineering, N.I.T Rourkela for their extreme help throughout my course of study at this institute.

National Institute of Technology

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CERTIFICATE

This is to certify that the thesis entitled “**To study the different industrial applications of PLC through ladder diagrams**”, submitted by Mr. VISHAL KUMAR ALOK and Mr. AJAY GOEL in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in ‘ELECTRONICS & INSTRUMENTATION’ Engineering at the National Institute of Technology (NIT), Rourkela is an authentic work carried out by them under my supervision.

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List of figures:-

Contents

Chapter 1

Need of PLC

Before PLCs came into existence;sequencing, safety interlock logic for manufacturing, and other controls were accomplished using physical relays,timers,and dedicated closed-loop controllers.

A relay is a simple device that uses a magnetic field to control a switch .When a voltage is applied to the input coil,the resulting current creates a magnetic field to control a switch.When a voltage is applied to the input coil,the resulting current creates a magnetic field.The magnetic field pulls a metal switch (or reed) towards it and the contacts touch, closing the switch. The contact that closes when the coil is energized is called Normally Open(NO).The Normally closed (NC) close when the input coil is not energized and open when the input coil is energized.

But the control industries were looking forward to eliminate the high costs associated with inflexible, relay controlled systems . The specifications required a solid-state system with computer flexibility which must be able to

(1) survive in an industrial environment,
(2) be easily programmed and maintained by plant engineers and technicians, and
(3) be reusable.

Such a control system would reduce machine downtime and provide expandability for the future.

Some of the initial specifications included the following:-

- The new control system had to be price competitive with the use of relay systems.
- The system had to be capable of sustaining an industrial environment.
- The input and output interfaces had to be easily replaceable.
- The controller had to be designed in modular form, so that subassemblies could be removed easily for replacement or repair.
- The control system needed the capability to pass data collection to a central system.
- The system had to be reusable.
- The method used to program the controller had to be simple, so that it could be easily understood by plant personnel.

The first programmable controllers:-

By 1969 the first programmable controller was developed. These early controllers met the original specifications and opened the door to the development of a new control technology.

The first PLCs offered relay functionality and replaced the original hardwired **relay logic**, which used electrically operated devices to mechanically switch electrical circuits. They met the requirements of modularity, expandability, programmability, and ease of use in an industrial environment. These controllers were easily installed, used less space, and were reusable.

The controller programming, although a little tedious, had a recognizable plant standard: the ladder diagram format. By 1971 PLC had spread to other automation industries such as food and beverage, metals and manufacturing, pulp and paper.

The conceptual design of PLC:-

The first programmable controllers were more or less just relay replacers. Their primary function was to perform the sequential operations that were previously implemented with relays. These operations included ON/OFF control of machines and processes that required repetitive operations, such as transfer lines and grinding and boring machines. However, these programmable controllers were a vast improvement over relays. They were easily installed, used considerably less space and energy, had diagnostic indicators that aided troubleshooting, and unlike relays, were reusable if a project was scrapped.

Although PLC functions, such as speed of operation, types of interfaces, and data-processing capabilities, have improved throughout the years, their specifications still hold to the designers' original intentions—they are simple to use and maintain.

Today's Programmable Controllers:-

Many technological advances in the programmable controller industry continue today. And these have led to many hardware (physical components) and software (control program) upgrades. The following list describes some recent hardware and software enhancements:-

- Faster scan times are being achieved using new, advanced microprocessor and electronic technology.

- Small, low-cost PLCs , which can replace four to ten relays, now have more power than their predecessor, the simple relay replacer.
- Mechanical design improvements have included rugged input/output enclosure and input/output systems that have made the terminal an integral unit.

Figure 1.1 Small PLC with built-in I/O and detachable ,handheld programming unit

- High-density input/output (I/O) systems (see Figure 1-3) provide space-efficient interfaces at low cost.

- Intelligent, microprocessor-based I/O interfaces have expanded distributed processing. Typical interfaces include PID (proportional - integral-derivative), network, CANbus, fieldbus, ASCII communication, positioning, host computer, and language modules (e.g., BASIC, Pascal).

- Special interfaces have allowed certain devices to be connected directly to the controller. Typical interfaces include thermocouples, strain gauges, and fast-response inputs.

- Small PLCs have been provided with powerful instructions, which extend the area application for these small controllers.

- High-level languages, such as BASIC and C, have been implemented in some controllers' modules to provide greater programming flexibility when communicating with peripheral devices and manipulating data.

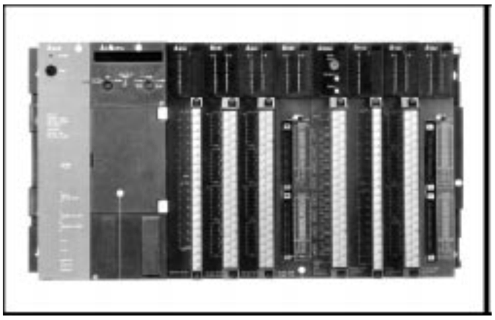


Figure 1.2 PLC system with high density I/O(64 point nodules)

- Advanced functional block instructions have been implemented for ladder diagram instruction sets to provide enhanced software capability using simple programming commands.

- Diagnostics and fault detection have been expanded from simple system diagnostics, which diagnose controller malfunctions, to include machine diagnostics, which diagnose failures or malfunctions of the controlled machine or process.

- Floating-point math has made it possible to perform complex calculations in control applications that require gauging, balancing, and statistical computation.

Chapter 2

What is PLC

Introduction:-

A programmable logic controller ,commonly known as PLC, is a solid state, digital , industrial computer using integrated circuits instead of electromechanical devices to implement control functions. It was invented in order to replace the sequential circuits which were mainly used for machine control. They are capable of storing instructions,such as sequencing, timing,counting, arithmetic, data manipulation and communication,to control machines and processes.

According to NEMA(National Electrical Manufacture's Association ,USA),the definition of PLC has been given as

"Digital electronic devices that uses a programmable memory to store instructions and to implement specific functions such as logic , sequencing, timing, counting, and arithmetic to control machines and processes."

Figure below illustrates conceptual diagram of PLC application

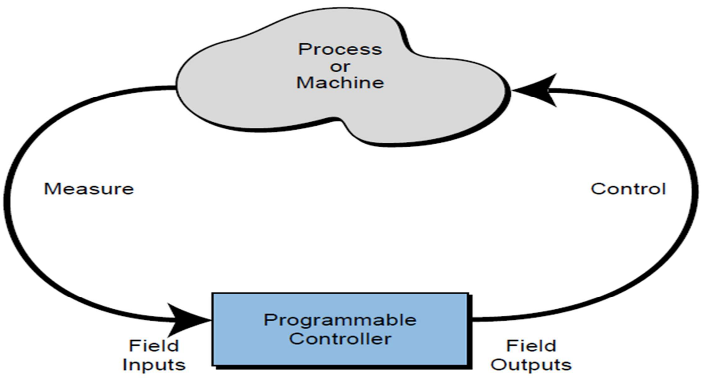


Figure 2.1 PLC conceptual application diagram

Basic parts of PLC:-

All programmable controllers contain a CPU, memory, power supply, I/O modules, and programmable devices. Basic parts of the PLC are as follows:-

(1) Processor
(2) Memory
(3) Input/output devices
(4) Programming panel or unit
(5) Power supply

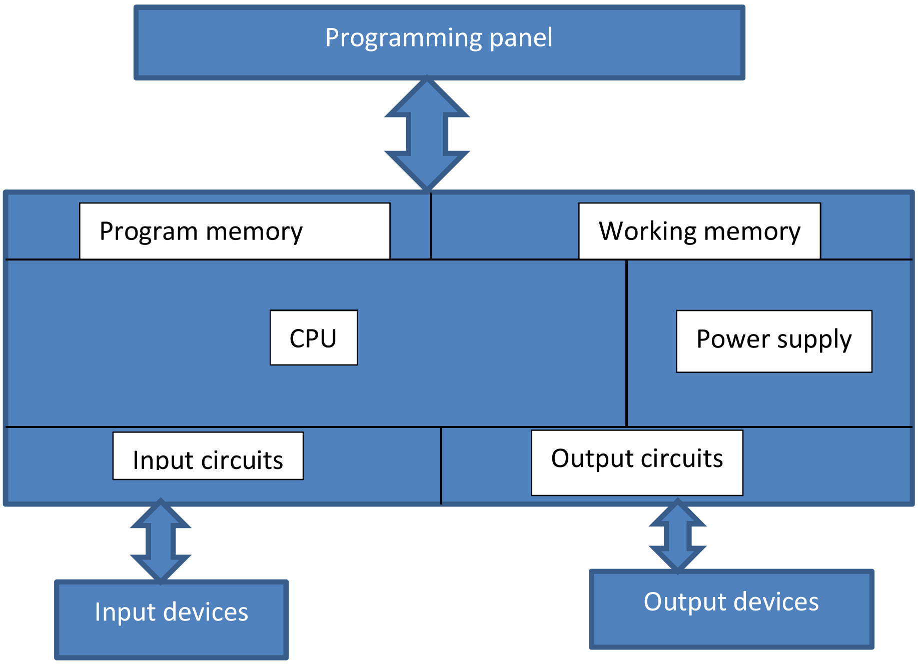


Figure 2.2 Basic parts of PLC

Processors module:-

Processor module is the brain of the PLC. Intelligence of the PLC is derived from microprocessor being used which has the tremendous computing and controlling capability. Central processing –unit (CPU) performs the following tasks:-

- Scanning
- Execution of program
- Peripheral and external device communication
- Self- diagnost

Power of PLCs depends on the type of microprocessors being used. Small size PLCs use 8-bit microprocessors where as higher order controllers use bit-slice microprocessor in order to achieve faster instruction execut

Modern day PLCs vary widely in their capabilities to control real world devices, like some processors are able to handle the I/O devices as few as six and some are able to handle 40000 or more. The no. of input/output control of PLCs depends on the, hardware, software, overall capacity and memory capability of the PLCs.

The CPU upon receiving instruction from the memory together with feedback on the status of the I/O devices generates commands for the output devices. These commands control the devices on a machine or a process. Devices such as solenoid valves, indicator lamps, relay coils and motor starters and typical loads to be controlled.

The machine or process input elements transmit signal to input modules which in turn, generates logic signal to the CPU.CPU monitors the input like selector switches, push buttons etc.

Operating system is the main workhouse of the system and hence performs the following tasks:-

1. Executions of application program
2. Management of memory
3. Communication between programmable controller and other units
4. i/o handling of interfaces
5. resource sharing
6. diagnostics

note:- operating system stored in ROM(non –volatile) memory, whereas application program are stored in RWM(read-write memory).

Input modules:-

There are many types of input modules to choose from. The type of input module selection depends upon the process, some example of input modules are limit :-switches, proximity switches and push buttons etc. nature of input classification can be done in three ways, namely:-

- low/high frequency
- analog/digital (two-bit, multi-bit)
- maintained or momentary
- 5V/24V/110V/220V switched

Some most industrial power systems are inherently noisy:- electrical isolation is provided between the input and the processor. Electromagnetic interference (EMI)

And radio frequency interference (RFI) can cause severe problems in most solid state control systems. The component used often to provide electrical isolation within I/O cards is called an optical isolator or opto-coupler. typically, there are 8 to 32 input points on any one input modules. Each input point is assigned a unique address by the processor.

Output modules:-

Output modules can be used for devices such as solenoids, relays, contractors, pilot lamps and led readouts. Output cards usually have 6 to 32 output points on a single module. Output cards , like input cards , have electrically isolation between the load being connected and the PLC. Analog output cards are a special type of output modules that use digital to analog conversion. The analog output module can take a value stored in a 12 bit file and convert it to an analog signal. Normally , this signal is 0-10 volts dc or 4-20ma. This analog signal is often used in equipment , such as motor-operated valves and pneumatic position control device. Each output point is identified with a unique address.

Addressing scheme:-

Each i/o device has to be identified with a unique address for exchange of data. Different manufacturer apply different method to identify i/o devices. One of the addressing schemes may be "X1 X2 X3 X4 X5" where

- X1 = input or output designation fixed by hardware (i/p = 1, o/p = 0)
- X2 = i/o rack number in PLC (user designation)
- X3 = modules slot number in i/o rack (fixed by hardware)
- X4 X5 = terminal number (fixed by hardware)
  For example," 1 2 3 13" implies that input is at rack 2 , module slot no.3 and terminal address no.13.

Programming unit:-

It is an external, electronic handheld device which can be connected to the processors of the PLC when programming changes are required. Once a program has been coded and is considered finished, It can be burned in to ROM. The contents of ROM cannot be altered, as it is not affected by power failure. Now a days EPROM/EEPROM are provided in which program can be debugged at any stage. Once the program is debugged, programming unit is disconnected ; and the PLC can operate process according to the ladder diagram or the statement list.

Communications in PLC:-

There are several methods how a PLC can communicate with the programmer, or even with another PLC. PLCs usually built in communication ports for at least RS232, and optionally for RS 485, and Ethernet. Modbus is the lowest common denominator communication protocol. Others are various fieldbuses such as profibus, interbus-s, foundation field bus, etc.

PLCs are becoming more and more intelligent .in recent years, PLCs have been integrated in to industrial networks, and all the PLCs in an industrial environment have been plugged in to a network. The PLCs are then supervised by a control center. There exist many types of networks, SCADA (supervisory control and data acquisition)

Operation of PLC :-

During program execution , the processor reads all the inputs , and according to control application program , energizes and de-energizes the outputs. Once all the logic has been solved, the processors will update all the outputs. The process of reading the inputs, executing the control application program, and updating the output is known as scan.

During the scan operation, the processor also performs housekeeping tasks.

The inputs to the PLCs are sampled by processor and the contents are stored in memory. Control program is executed, the input value stored in memory are used in control logic calculations to determine the value of output. The outputs are then updated.

The cycle consisting of reading of inputs, executing the control program, and actuating the output is known as “scan” and the time to finish this task is known as “scan time” . The speed at which PLC scan depends upon the clock speed of CPU. The time to scan depends upon following parameter:-

- Scan rate
- Length of the program
- Types of functions used in the program

  Faster scan time implies the inputs and outputs are updated frequently. Due to advance techniques of ASIC (application specific integrated circuit) within the microcomputer for specific functions , scan time of different PLCs have reduced greatly.

Chapter 3

Programming languages

As PLCs have developed and expanded, programming languages have developed with them. Programming languages allow the user to enter a control program into a PLC using an established syntax. Today's advanced languages have new, more versatile instructions, which initiate control program actions. These new instructions provide more computing power for single operations performed by the instruction itself.

In addition to new programming instructions, the development of powerful I/O modules has also changed existing instructions. These changes include the ability to send data to and obtain data from modules by addressing the modules' locations. For example, PLCs can now read and write data to and from analog modules. All of these advances, in conjunction with projected industry needs, have created a demand for more powerful instructions that allow easier, more compact, function-oriented PLC programs.

The three types of programming languages used in PLCs are:-

- Ladder
- Boolean
- Grafcet

The ladder and Boolean languages essentially implement operations in the same way, but they differ in the way their instructions are represented and how they are entered into the PLC. The Grafcet language implements control instructions in a different manner, based on steps and actions in a graphic oriented program.

Ladder language:-

For ease of programming the programmable controller was developed using existing relay ladder symbols and expressions to represent the program logic, needed to control the machine or process. The resulting programming language, which used these original basic relay ladder symbols, was given the name **ladder language**. Figure below illustrates a relay ladder logic circuit and the PLC ladder language representation of the same circuit.

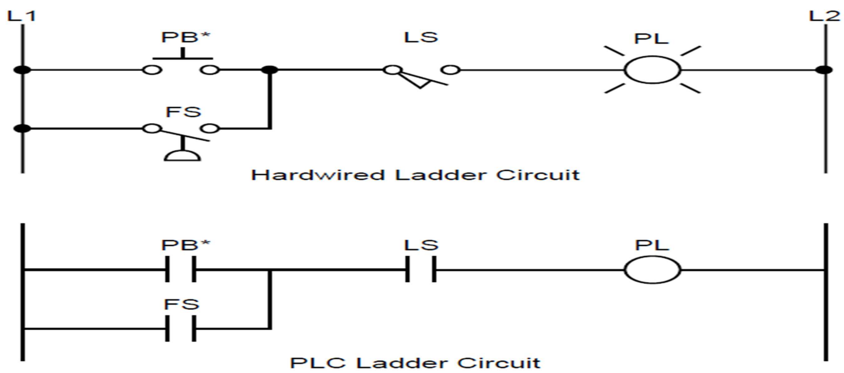


Figure 3.1 Hardwired logic circuit and its PLC ladder diagram representation

The evolution of the original ladder language has turned ladder programming into a more powerful instruction set. New functions have been added to the basic relay, timing, and counting operations. The term *function* is used to describe instructions that, as the name implies, perform a function on data i.e. handle and transfer data within the programmable controller.

New additions to the basic ladder logic also include function blocks, which use a set of instructions to operate on a block of data. The use of function blocks increases the power of the basic ladder language, forming what is known as **enhanced ladder language**.

The format representation of an enhanced ladder function depends on the programmable controller manufacturer; however, regardless of their format, all similar enhanced and basic ladder functions operate the same way.

Boolean language:-

Some PLC manufacturers use **Boolean language**, also called *Boolean mnemonics*, to program a controller. The Boolean language uses Boolean algebra syntax to enter and explain the control logic. That is, it uses the AND, OR, and NOT logic functions to implement the control circuits in the control program. Figure below shows a basic Boolean program.

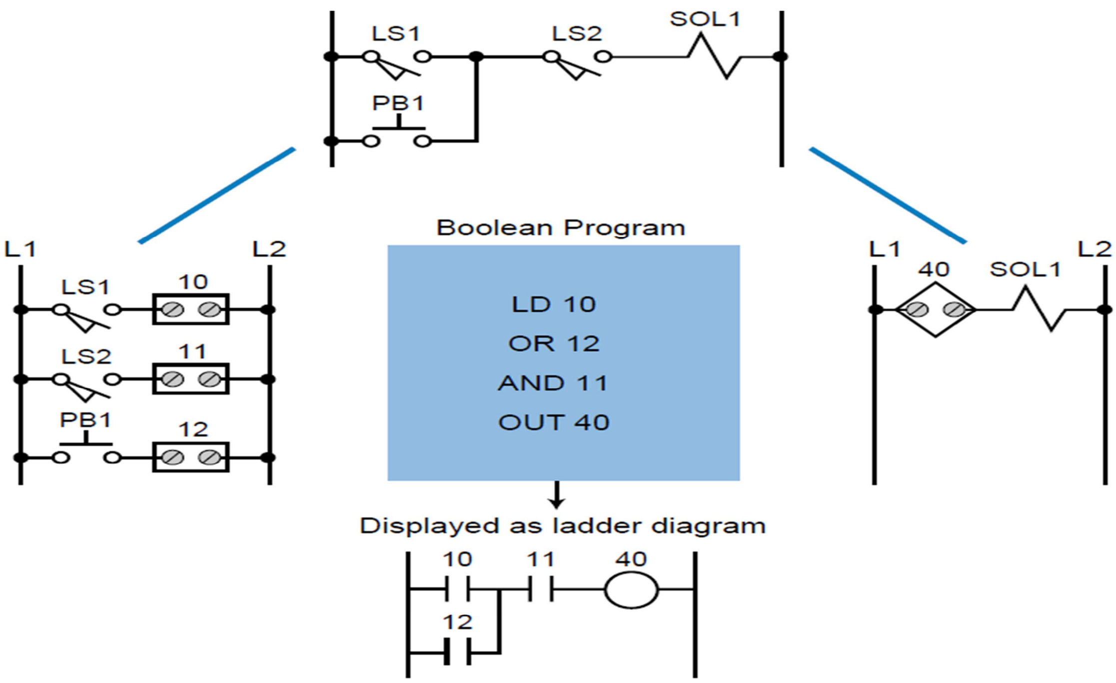


Figure 3.2 Hardwired logic circuit and its Boolean expression

The Boolean language is just the another way of entering the control program in the PLC, rather than an actual instruction-oriented language. When displayed on the programming monitor, the Boolean language is usually viewed as a ladder circuit instead of as the Boolean commands that define the instruction.

Grafcet:-

Grafcet (Graphe Fonctionnel de Commande Étape Transition) is a symbolic, graphic language, which originated in France, that represents the control program as steps or stages in the machine or process. In fact, the English translation of Grafcet means “step transition function charts.” Grafcet is the foundation for the IEC 1131 standard’s sequential function charts (SFCs), which allow several PLC languages to be used in one control program.

Figure below illustrates a simple circuit represented in Grafcet. Note that Grafcet charts provide a flowchart-like representation of the events that take place in each stage of the control program. These charts use three components— steps, transitions, and actions—to represent events. The IEC 1131 standard’s SFCs also use these components; however, the instructions inside the actions can be programmed using one or more possible languages, including ladder diagrams.

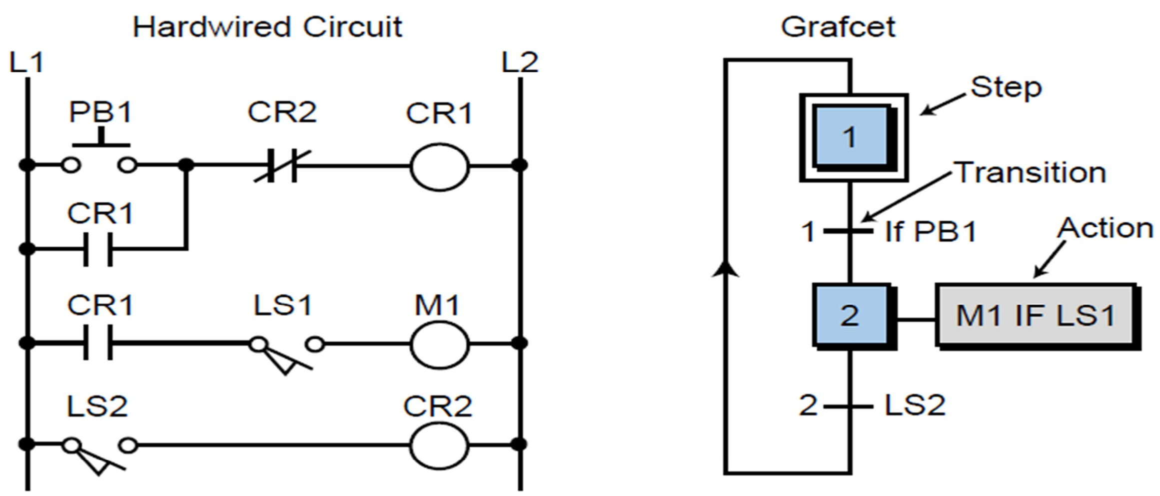


Figure 3.3 Hardwired logic circuit and its grafcet representation

Once programmed in the PC, the Grafcet instructions can be transferred to a PLC via a translator or driver that translates the Grafcet program into a ladder diagram or Boolean language program. Using this method, a Grafcet software manufacturer can provide different PLCs that use the same “language.”

Chapter 4

Industrial applications

1.

Continuous bottle filling system:-

This is one of the important application of PLC in the bottle filling industry where we want our bottles, which are moving on the conveyor belt, to be automatically detected at the appropriate position and get it filled by any desired liquid and also after getting filled the queued bottle gets chance to be filled. If this whole process is carried out manually it will really take a long time and also the quantities will be quite lesser. So PLC becomes requisite controller for these types of industry.

Here also just a small demonstration of the process was performed with the help of PLC where a ladder diagram was created to control the process and the ladder diagram was run the PLC trainer kit to see its justification.

Objective:-

We will implement a control program that detects the position of a bottle via a limit switch then waits for 0.5 secs, and then fills the bottle until a photodetector detects the filled condition of the bottle. After the bottle is filled ,the buzzer sounds and the control program will again wait for 0.7 secs. before moving to the next bottle .Until the limit switch signals ,the feed motor,M1 runs while there are fixed rollers which carries the filled bottles. Motor,M2 keeps running after the process has been started.

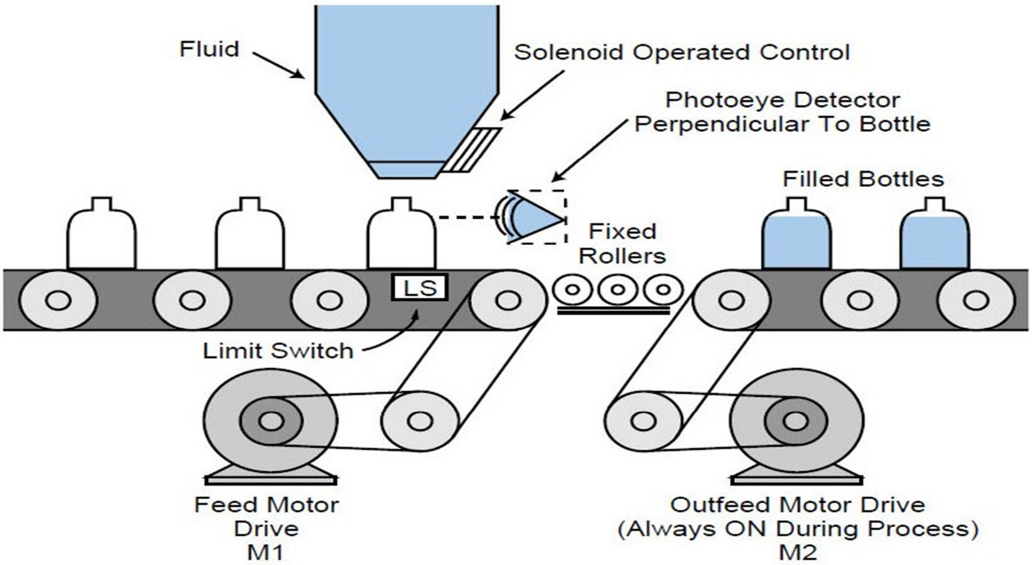


Figure 4.1 Bottle filling system

Inputs	address
Start	I0:15
Stop	I1:15
Limit switch(LS)	I2:15
Photo detector(PE)	I3:15

Outputs	address
Feed motor(M1)	O0:15
Outfeed motor(M2)	O1:15
Solenoid valve(S1)	O2:15
Light(L1)	O3:15
Buzzer(B1)	O4:15

Table 1: Inputs and outputs employed

Ladder diagram:-

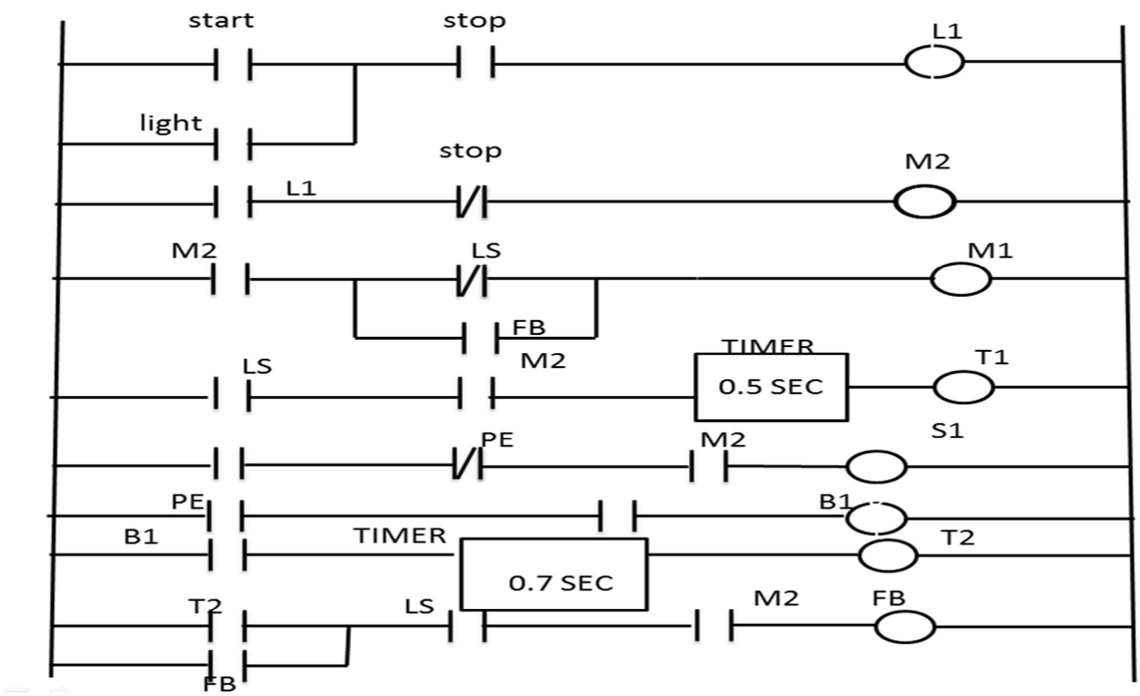


Figure 4.2 ladder diagram for bottle filling system

Obesrvation:-

Once the start button is pressed the green light (L1) turns ON and remains ON until stop button is pressed.As light turns ON outfeed motor(M2) starts running.After M2 runs and if either limit switch(LS) has not signaled or filled bottle condition is fulfilled motor(M1) starts.After limit switch has signaled timer,T1 gets activated. After T1 gives done (DN)signal and photoeye detector (PE) is disabled ,solenoid valve gets in operation.As PE signals solenoid stops and buzzer(B1) sounds after which timer,T2 gets enabled which stops the process for 0.7 seconds. Once the filled bottle condition is activated the cycle starts again.

The ladder diagram was successfully checked in the PLC simulator and all the prescribed conditions were observed completely.

2.

Batch mixing system:-

This is another commonly applied application of PLC where two liquids are mixed in required proportion to form a batch .Rate of the flow is already fixed. We only control the time of the flow. Level of the liquids in the tank are sensed by the level sensor switches

Objective:-

We try a simple blending of water and acid in a container where we only have three level sensors(L1,L2, and L3) and two liquids flowing in through two solenoid valves, solenoid a(water control) and solenoid b(acid control)and draining out through solenoid c(blend outflow).The batch is to be controlled by timer. After required level of blend is sensed (by L1)the mixer runs for 3 mins. by the motor. They are mixed in ratio of 3:2. The process initiates with the drain valve open, water and acid valves closed, mixer motor is off, and the tank is empty.

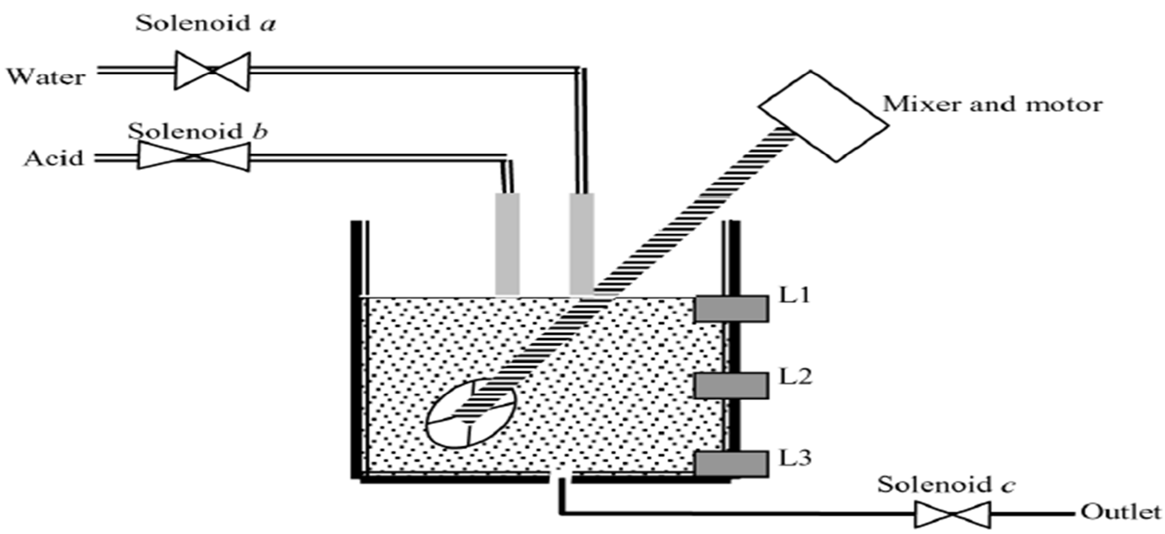


Figure 4.3 Batch mixing system

Ladder diagram:-

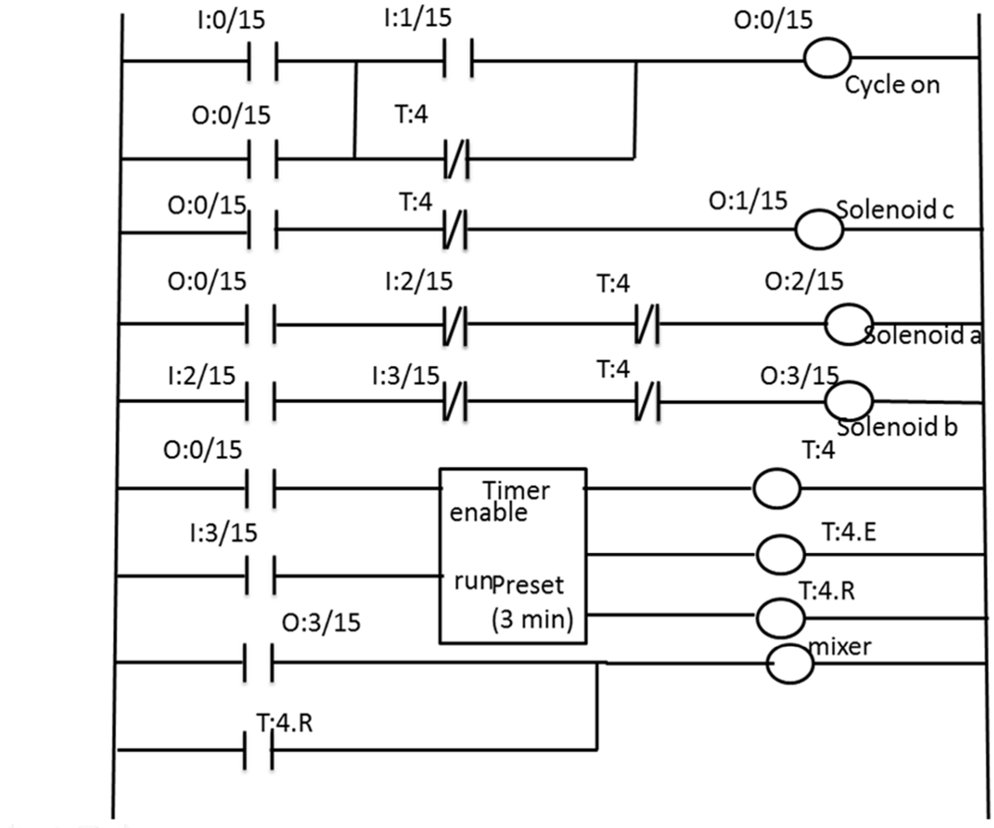


Figure 4.4 Ladder diagram for batch mixing system

Observation:-

When start button is pressed water is filled upto L2 and it ends as L2 is closed. First of all as start is pressed output O:0/15 turns ON and remains ON until tank is emptied. Rung 2 closes normally open drain valve, before timer T:4 activates. Rung 3 energises solenoid a until L2 doesn't signal, once it signals solenoid a gets de-energised.Then motor is turned ON and mix it for 3 mins. Similarly acid is filled upto L3 by solenoid b.as level gets detected by L3 solenoid b de-energises .And then mixer gets started and it runs for 3 minutes. After time delay of 3 mins solenoid c opens and the blend gets drained out .Once the blend gets out completely ,the process cycle restarts.

The ladder diagram was successfully checked in the PLC simulator and all the prescribed conditions were observed completely.

3.

3 -stage air conditioning system:-

A simple air conditioner consists of a single air compressor motor which gets switched off when temperature of the space being controlled falls below the setting on the thermostat. Thermostats are provided with a differential setting to avoid on and off of the compressor motor. The three stage air conditioning system helps in conservation of electrical power.

Objective:-

There are two motors compressors in the system. One is of low horsepower and other one is of high horsepower rating. These motors are designated as C1 and C2 in the case. The system is installed in a hall to maintain the temperature between 20^0C-24^0C depending on the number of viewers in the hall and the atmospheric temperature.

The motors of C1 and C2 are run on three conditions of the thermostats. The three conditions described below are also the control requirements of the air conditioning system:-

1. Compressor 1 and compressor 2 should turn on when the temp. of the hall is above 28^0C .
2. Only compressor 2 should turned on when the temp. of the hall is above 24^0C and below 28^0C.
3. Only compressor 1 is turned on when the temp. is above 20^0C and below 24^0C.

   A pre- condition for running any compressor is that chilling water flow switch FS1 should be closed. Chilling water flow necessary to take away heat from the compressed cooling water.

Three thermostat with different settings are used for the control of compressor motor running In three different stages described above. The three thermostats T1, T2, T3, are set at temp 20^0C, 24^0C and 28^0C respectively.

The control of three stages with three the thermostats and Flow switch (FS1) of air conditioning system can be understood from the control circuit shown In fig.4.5.

The start push button, stop push button and overload contacts for compressor motor have not been shown in the circuit for sake of simplicity.

Working of the control circuit :-

(1) When chilled water flow is maintained, flow switch FS1 will actuate and close its contacts. Closing of contact FS1 causes application of high logic signal to terminal 2 of all gates.

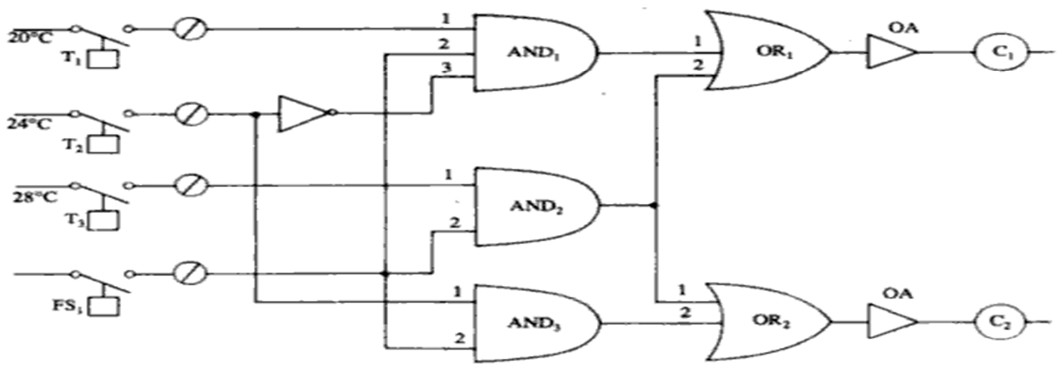


Figure 4.5 logic control circuit for 3 stage air conditioning system

(2) When the temp. in the cinema hall will be above 28^{0}C the contacts of all the thermostat will be closed. Closed contact of T1 will give a high input to terminal 1 of AND1 but closed contact of T2 will give low logic to terminal 3 of AND1 as there is a not gate in series. The output of AND1, therefore becomes low.

(3) Closed contact of T3 will give a high input to terminal 1 of AND2 while the other terminal 2 is already high due to closure of FS1 AND2 thus gives a high output which is applied to both OR1 and OR2,as each terminal of OR1andOR2 is now high, their output is also high. Output from OR1 leads to energisation of contactor C1 and output from OR2 leads to energisation of contactor C2 through their respective amplifiers. Thus compressor 1 and 2 will run when temp. in the hall will above 28^{0}C.

(4) When the hall temp. is below 28^{0}C and above 24^{0}C, contact of thermostat T3 will open, While contacts of T 1andT 2 are closed. Due to open contact of T3 there is low signal at terminal 1 of AND2 and therefore its output is low. Output of AND1 is also low as closed Contact of T2 gives a low signal at terminal 3 due to a not gate in series, in this case AND3 Will have a high output as its input terminal1 has high signal from the closed contact of Thermostat T2 ,it is to be noted that supply to terminal1 of AND3 is taken prior to the NOT Gate. High output from AND3 goes to terminal 2 of OR2 which then gives a high output. This output energises contactor C2 through the amplifier. Thus compressor 2 will run only when the temperature is above 24^{0}C but below 28^{0}C.

(5) When the temp. falls below 24^{0}C contact of thermostat T2 opens and output of AND3 will Go low due to a low signal in its input terminal the open contact of T2 will however give a high signal to terminal 3 of AND 1 (due to not gate in series), It will get switched on as its terminal 1 and2 are already high. The high output from and1 then goes to terminal 1 of or1 which then gives a high output to energise contactor C1.thus one compressor will run when temp. is below 24^{0}C but above 20^{0}C. When temp. falls below 20^{0}C, contact of thermostat T1 also opens and terminal 1 of AND1 goes low and it is switched off .Thus Compressor 1 also stops when temp. falls below 20^{0}C.

(6) Compressor 1 continues to run if temp. in the hall remains 20^{0}C -24^{0}C, if due to more viewers in the hall, compressor 1 is unable to maintain, temp. below 24^{0}C. compressor 1 will be switched off. If the load is still more and compressor 2 alone can not cope up and temp. goes above 28^{0}C then compressor 1 will also start to bring down the temperature.

Ladder diagram:-

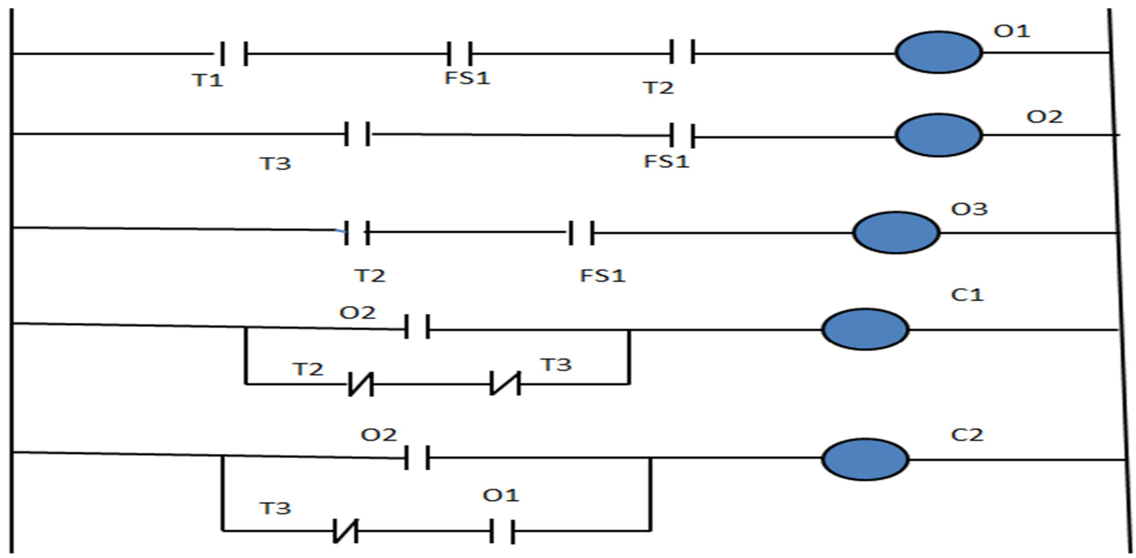


Figure 4.6 Ladder diagram for 3 stage air conditioning system

Observation:-

The ladder diagram was satisfactorily realized in the lab and all the conditions were tested .The outputs are same as expected

4.

Control of Planar machine:-

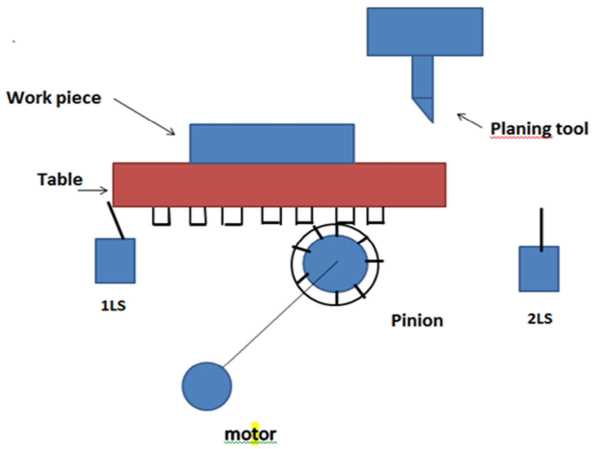


Figure 4.7 Planar machine

In this machine, the work piece or the job placed on the table moves to and fro by rack and pinion arrangement mounted on the shaft of the squirrel cage motor. Here the cutting tool is fixed while the job placed on the table is worked upon by the movement of table. Movement of the table is controlled between two limits left and right by switches 1LS and 2LS. When the table moves left to right, tool works on the job while it remains ideal during right to left motion of the table. At the end of right to left motion, tool gets feed for the next cut on the job. Various control requirements for the job are as follows:-

(1) The motor is to be start manually by pressing start push-button. Once the motor starts it reversed automatically at the end of right or left stroke by limit switches2LSand1LS.
(2) There should be provision of jogging the motor by jog push button.
(3) If the machine table is lying in between extreme position, machine should fail to start. Selection of initial direction of travel should be possible through right and left push button, PBR and PBL.
(4) There should be delay in starting the motor in left to right stroke so as to allow the tool To get the feed for the fresh cut on the job.
(5) The machine should stop on pressing the stop push –button or on over load tripping of motor.
(6) Interlocking of coolant pump motor(running) should be provided as a precondition for the starting of machine.

Control circuit for the machine adhering to the above mentioned control requirement shown in fig:-

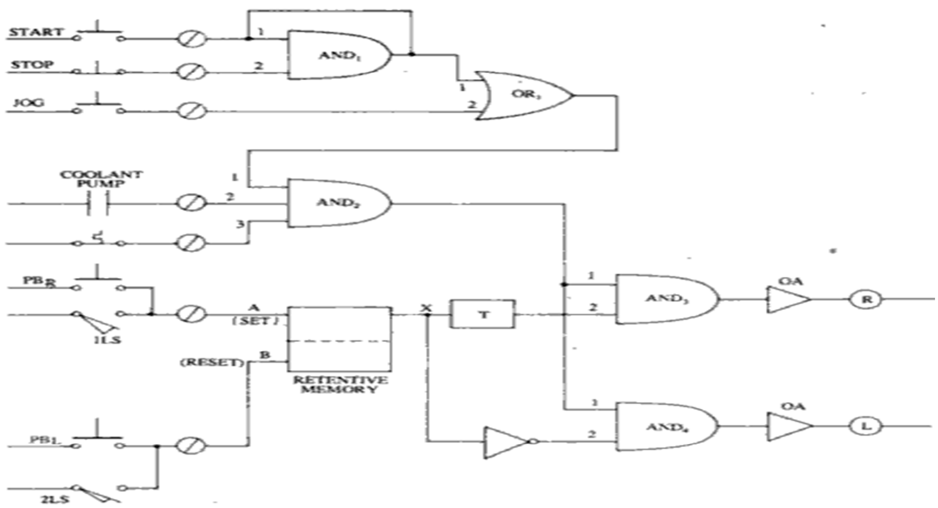


Figure 4.8 logic control circuit for planar machine

There are two major sectors of this control circuit. One is the control of starting and stopping of the motor, and the other is the automatic reversing control:-

Working of the circuit :-

1. When start-push button is pressed, input terminal 1 of AND1 becomes high,its output also goes high as its input terminal2 is also high due to close contact of stop-push button. Output is fed back to terminal1 for holding the output high.
2. Output of AND_1 appears at terminal 1 of OR1 making the output of OR1high which appears at terminal I of AND2. If motor overload relay contact is CLOSED and coolant pump motor is running, then terminals 2and 3 of AND2 also have a high signal. Thus all the three input terminals of AND2, are high and so its output goes high.

3. Output of AND2 appears at terminal 1 of AND3 and AND4 Depending upon the condition of memory element whether it is in set mode or in reset, either AND3 or AND_4 output will go high and will energies their respective contactor R or L. Desired direction

of travel may however be selected by pressing the right or left traverse push buttonsPB3 or PB4before pressing the START-push button.

4. To understand the reversing action of circuit, it is assumed that initially the machine table is in extreme left position so that the limit switch ILS is in actuated condition and its normally open (NO) contact is closed. Thus, a high signal appears at terminal A of the retentive memory through closed contact of ILS. Memory element gets set and its output terminal X goes high.

5. High output from terminal X appears at terminal 2 of AND3 after some delay set by the timer T while at terminal 2 of AND4 a low signal appears because of the NO T gate being in series with the output from X.

6. As both the terminals I and 2 of AND3, arc now high, its output becomes high which energize motor contactor R through the amplifier. Machine table thus moves in right direction.

7. When extreme right position is reached, limit switch 2LS gets actuated. Is normally Open (NO) contact closes and resets the memory element. Output at terminal X goes low and thus terminal 2 and AND3 also becomes low. Output of AND3 therefore goes low and contactor R is de-energized. At the same time when memory element gets reset, terminal 2 of AND4 goes high due to a NOT gate inverting the low output from X

8. Thus, due to actuation of limit switch 2LS terminal 2 and AND4 goes high while its terminal 1 is already high. Hence, a high output appears which energize motor contactor L through the amplifier. Motor now runs in reverse direction to move the table from right to left.

9. when the table reaches extreme left position limit switches ILS gets actuated and memory element is set thus terminal 2 of AND4 goes low and its output becomes low. Contactor l is therefore is de-energized. After a delay set on timer Again Contactor R is energized as output of AND3 becomes high. The to and fro motion, due to setting and resetting of memory elements by actuation of limit switches. Continues till the stop push Button is pressed or overloads trips to make the terminal1 of AND3 and AND4 low.

10. if the machine table is required to be moved slowly in steps for the adjustment of the tool with respect to the job position then jog- push button.

Ladder diagram:-

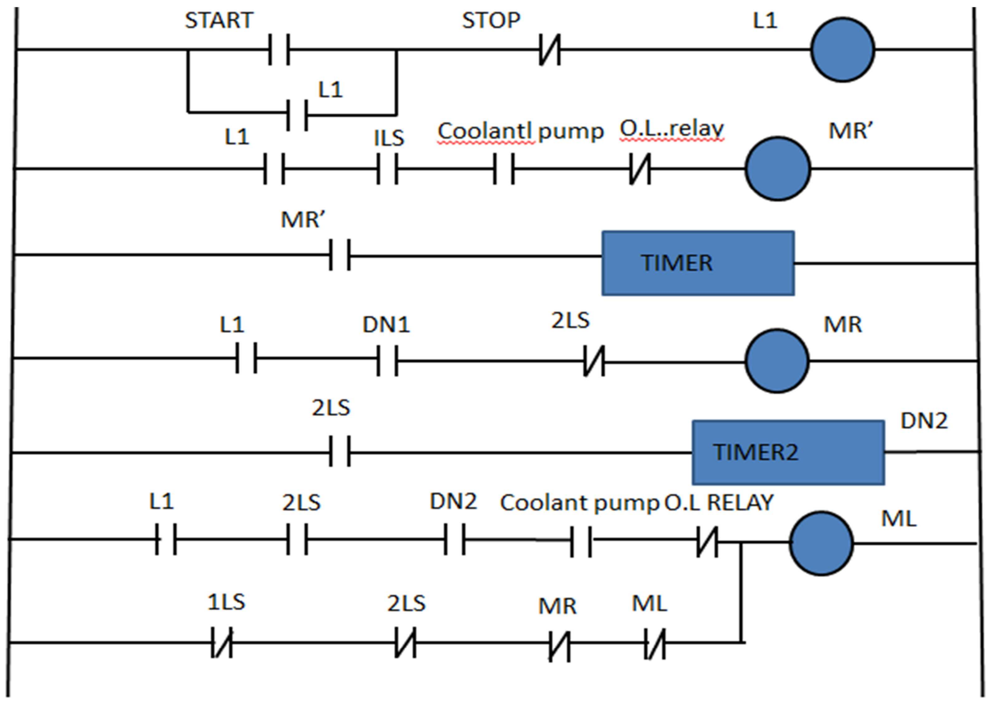


Figure 4.9 Ladder diagram for planar machine control

Observation:-

The ladder diagram was satisfactorily implemented in the lab satisfying all the desired conditions. So the process can be easily controlled by the PLC ladder diagram.

5.

Speed control of dc motor:-

Speed control of a motor means the intentional variation of speed according to the requirement of the work-load connected with the motor. This can be done by mechanical means ,such as by using stepped pulleys, a set of change gears,a friction clutch mechanism,etc. However control of speed by electrical means has greater advantages over mechanical speed controls.The dc motors offer easy speed control and that's why dc motors are preferred over other types of motors in many applications. Various speed control method can be obtained from its expression which is:-

$$N=V - I_aR_a/K\phi \quad \text{--} \quad 1.$$

Where:-

N=speed of motor
I_a=armature current
R_a=armature resistance
Φ=field flux
So it can be concluded that speed of dc motor depends upon

a. The applied voltage
b. The field flux
c. Drop in armature circuit resistance I_aR_a

And accordingly speed can be controlled by varying the above factors.

A. Speed control by varying the field flux:-

In shunt field winding motor ,variable resistor called field regulator is connected in series while in series motor a resistor called diverter is connected in parallel with series field winding. When field circuit resistance is varied ,the field current and so the flux varies.But by introducing field regulator ,the field circuit resistance can only be increased i.e. the field flux can only be decreased,and therby the speed of the motor can be increased.It is not possible to decrease motor's speed by this method.Similarly by increasing the diverter circuit resistance, the field current can be reduced and thereby the speed of series motor cab be increased.Reduction of speed is not possible by using diverter.

B. Speed control by connecting a resistance in series with armature:-

A reistance called the controller is connected in series with the armature .Here the speed of the motor can be reduced as desired. Using desired value of the controller resistance, the speed can be reduced or increased to a great extent. The field winding should be connected across the supply terminals, otherwise the flux produced will be badly affected and sufficient torque may not be produced to rotate the motor.

The disadvantages of this method are as follows:-

a. The overall efficiency of the system is low as much of the input energy is dissipated in the controller as heat.
b. The controller has relatively high cost.
c. The speed may vary largely with variation of load.

C. Speed control by controlling the voltage applied across the armature terminals:-

In this method of speed control the armature is supplied with a variable voltage with the help of a motor-generator set since the supply voltage available from the electricity authority cannot be varied at will.This system of speed control is also known as the Ward-Leonard system.If a reversing switch is incorporated,by changing the polarity of the armature supply terminals,speed can be varied in the opposite direction also.This system is advantageous over other system in following ways:-

a. it provides smooth control of speed over a wide range in both directions
b. The system is more efficient at low speeds as there are no resistors connected in series with the armature circuit.

We apply this strategy only to control the motor speed as other methods are lossy and inefficient. Here instead of adding extra motor- generator set we control speed by PLC. The PLC supplies control signals to the MOSFET switches .These control signals have variable duty cycle that depends on the speed required. Depending on the duty cycle the motor gets the average voltage and accordingly speed varies.

Consider the circuit shown below .Here we have a dc voltage source V, a resistor R, inductor L, diode D, and a semiconductor switch Q (shown here as an N-channel insulated gate MOSFET). The signal applied to the gate of the switch Q is a pulse train with constant frequency f (and constant period T), but with varying pulse width t. The amplitude of the signal applied to the gate will cause the switch to transition between cutoff and saturation with very short rise and fall times. The relative values of R and L are selected such that the time constant = L/R is at least 10 times the period T of the pulse train applied to the gate of Q. The long L/R time constant will have a low-pass filtering effect on the chopped output of the switch Q, and will effectively smooth the current into dc with very little ac component.

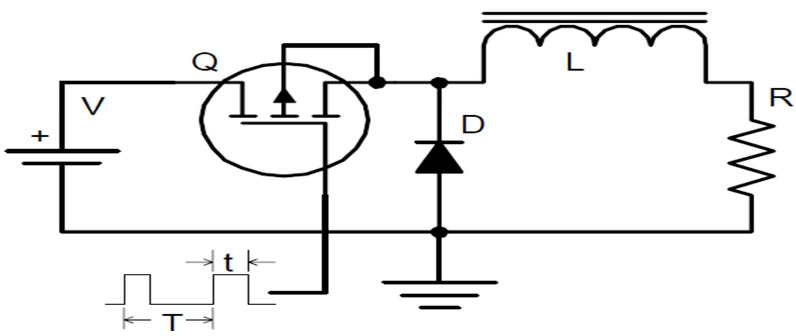


Figure 4.10 simple dc switch voltage controller

For the switch Q, the ratio of the on-time t to the period T is defined as the **duty cycle**, and is represented as a percentage between zero and 100%.For any duty cycle between 0% and 100%, the average resistor voltage will be a corresponding percentage of the voltage V and also the power transferred to the motor. For example, if we adjust the applied gate pulses so that the duty cycle is 35% (i.e., ON for 35% of the time, OFF for 65% of the time), then the voltage on the resistor R will be 35% of the input voltage V. This is because, during the time that the switch is ON, the inductor L will store energy; during the time the switch is OFF, the inductor will give up some of its stored energy keeping current flowing in the circuit through inductor L, resistor R, and the forward biased diode D (in this application, the diode is called a **freewheeling diode** or **commutation diode**).
As in the above figure we have resistance and inductor connected in series we can model dc armature as lumped resistance and lumped inductance in series.

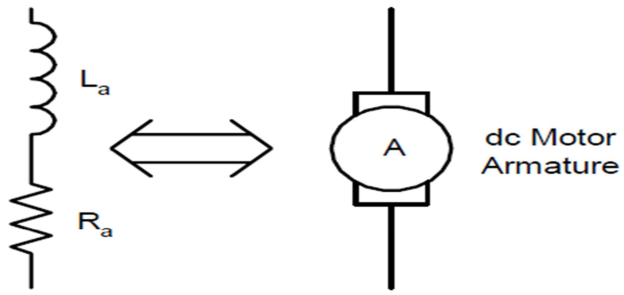


Figure 4.11 dc motor armature model

Since we can model the dc motor armature as a series resistance and inductance,
we can substitute the armature in place of the resistor and inductor in our dc switch circuit which looks as

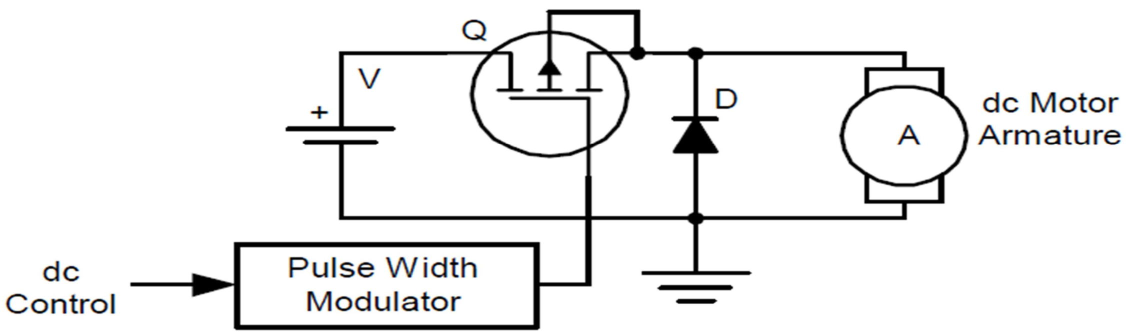


Figure 4.12 dc motor speed control

PLC implementation:-

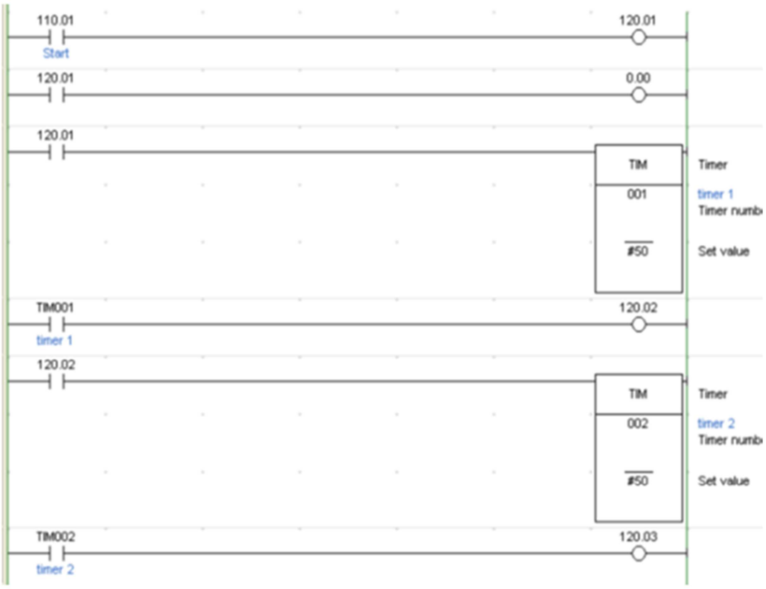


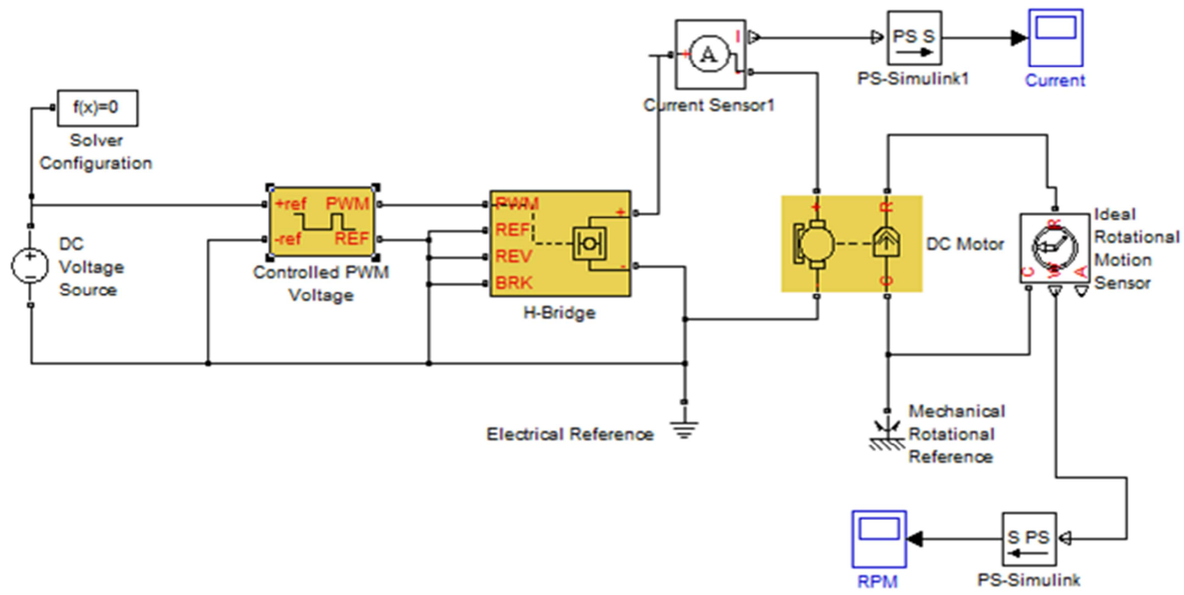
Figure 4.13 ladder diagram for generation of pulses

For generation of pulses ,first whole time period is set in counter by any n-bit according to resolution required. Now according to the percentage of rpm required with respected to maximum rpm of the motor , the counter is also set at the same percentage(value with respect to n-digit maximum value) as the voltage. We have comparator to check that value. Till fixed value signals passes while it remains off for remaining period of the pulse. In this way we generate signals of varying duty cycle pulses.

The ladder diagram when simulated gave the same result .Signal remained ON until the counter finished counting and became off for rest period.The process is repeated in every time period.

Matlab Simulink :-

We used matlab Simulink to study how the rpm of motor varied by changing the dc average supply to the motor and this dc supply voltage was varied by supplying the variable duty cycle signal through PLC.



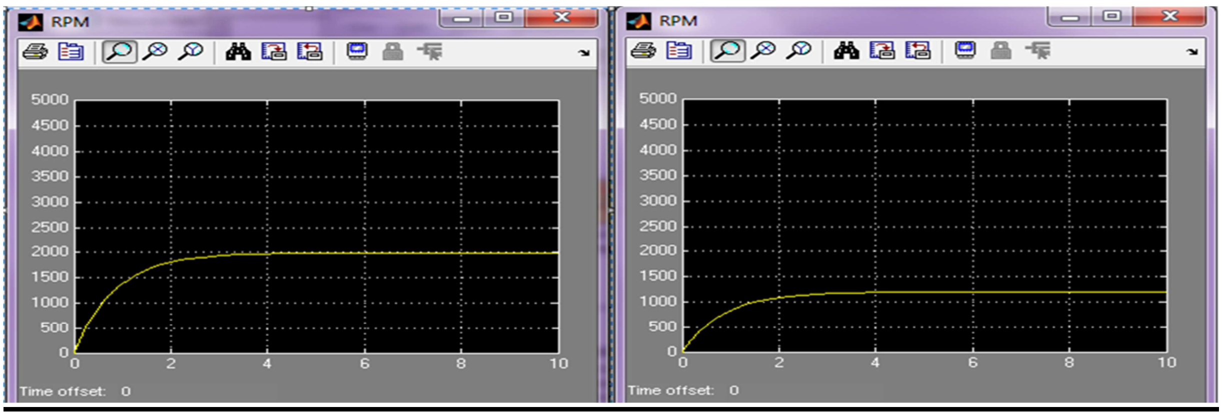


Figure 4.14 Variation of rpm when dc supply is 2.5 volts and 1.5 volts

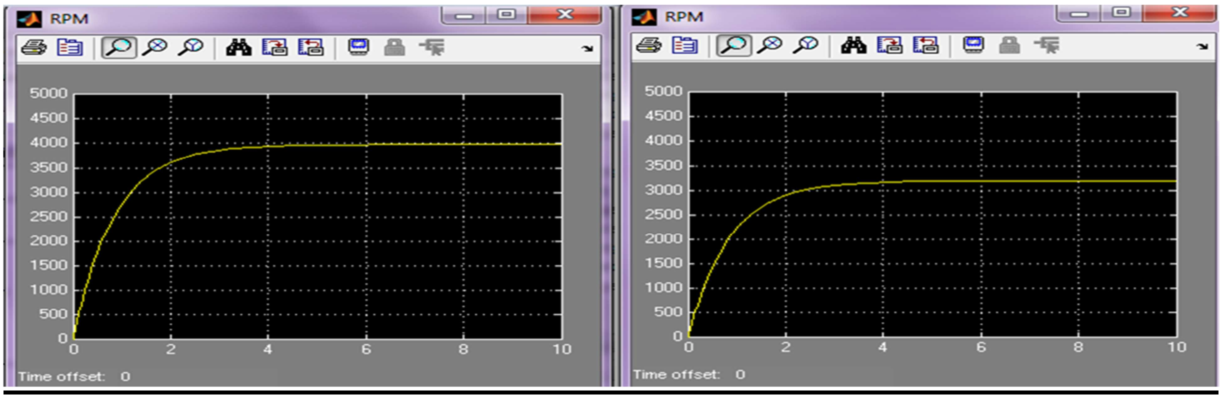


Figure 4.15 Variation of rpm at 5 and 3.5 volts.

So the speed control of dc motor is successfully performed with duty cycle variation with the help of PLC .

6.

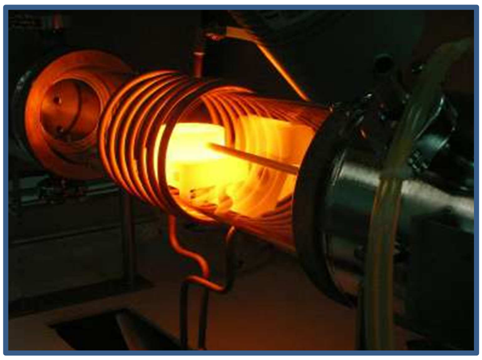
Automatic frequency control of induction heating:-

What is Induction heating?

Induction heating is a non-contact heating process and it uses high frequency electricity to heat materials that are electrically conductive. Since it is non-contact, the heating process does not contaminate the material being heated. It is also very efficient since the heat is actually generated inside the workpiece.

This can be contrasted with other heating methods where heat is generated in a flame or heating element, which is then applied to the workpiece. For these reasons, Induction Heating lends itself to some unique applications in industry. Let us take the case of platinum and gold jewellery manufacturing industry where the Induction heating is an important enabling technology .

The first reason for using induction heating is that the high melting point of platinum alloys dissolves the usual refractory materials, causing contamination of the melt ,when process is carried by other heating method and results in poor finished products. The second reason is the special mixture of oxy-gas and hydrogen required for melting platinum is often expensive and requires skilled labour to operate.



How it is carried out?

Theoretically it can be said that only 3 things are essential to implement induction heating:

1. A source of High Frequency electrical power,
2. A work coil to generate the alternating magnetic field,
3. An electrically conductive workpiece to be heated,

Practically ,there are several other systems and circuits required like water cooling system (to remove waste heat from work coil),impedance matching(for maximum power transfer) and power and frequency control circuitry(to control deviated power and resonance frequency)

For heating , source of high frequency electricity is used which drives a large alternating current through the work coil and passage of this current through the coil generates a very intense and rapidly changing magnetic field in the space within the work coil. The workpiece to be heated is placed within this intense alternating magnetic field.

Factors and parameters affecting heating in the work piece:-

1.Eddy currents:-

The arrangement of the work coil and the workpiece can be thought of as an electrical transformer. The work coil is like the primary where electrical energy is fed in, and the workpiece is like a single turn secondary that is short-circuited. This causes tremendous currents to flow through the workpiece. These are known as eddy currents.

The frequency of the induced Eddy currents in the work-piece is determined by the frequency of the power source. These eddy currents are induced into a peripheral layer of the work-piece known as the skin-depth (δ) or penetration depth which is characteristic of current flow at high frequency and this skin- depth is related as:-

$$\delta=(\rho/\mu\pi f)^{0.5} \quad \text{------------------------------} \quad 2.$$

Where:-

δ = penetration depth
ρ = resistivity of work-piece
f=frequency of eddy currents
μ = permeability of work-piece which in this case is the same as free space, since the work-piece is non-magnetic.

The skin depth is roughly where the current density has fallen to about one third its surface value. The current density falls off from the surface to the center of the workpiece and its rate of decrease is higher at higher frequencies, thus to decrease the skin-depth(for concentrated heating),high frequency is used. This skin depth is also dependent on two properties of the material, i.e., resistivity and relative permeability and these two factors get affected at high temperatures.

2.Skin effect:-

In addition to this, the high frequency used in induction heating applications gives rise to a phenomenon called skin effect. This skin effect forces the alternating current to flow in a thin layer towards the surface of the workpiece and this effect increases the effective resistance of the metal to the passage of the large current. Therefore it greatly increases the heating effect caused by the current induced in the workpiece.

3.Coupling Efficiency:-

Coupling efficiency is a measure of the amount of power transferred between the coil and workpiece. It is measure of how much the primary and secondary windings are closely coupled to reduce the flux leakage between them.
The efficiency of coupling in this case is dependent on the resistivity of the coil and that of the work-piece and is given by the equation below:-

$$\eta=1/1+(\boldsymbol{\rho}_c/\boldsymbol{\rho}_w\mu_w)^{0.5} \quad \text{--------------------------------} \quad 3$$

where:-

η = coupling efficiency between the coil and work-piece;
$\boldsymbol{\rho_c}$ = electrical resistivity of the heating coil (which is usually oof! copper tubing)
$\boldsymbol{\rho_w}$ = electrical resistivity of the work-piece
μ_w = relative permeability of the work-piece

Practical factors affecting coupling efficiency include:-

• Geometry of work-piece, which improves for a tightly packed, solid work-piece and decreases for a loosely packed work-piece due to leakage flux.
• Geometry of the heating coil, which improves for a closely wound coil around the work-piece. Other factors also concerned with geometry are the length of the coil and the number of coil turns.
• The material used for the heating coil. The higher the coil conductivity, the lower the I^2R losses in the coil, hence the more power transferred to the work-piece

4.Curie temperature:-

The heating of ferro-magnetic materials poses a special problem because of the Curie point. Above the Curie temperature the relative permeability of the material reduces to unity, which results in a large increase in skin depth.The equation regarding change in the permeability is given as:-

$$\rho_\theta = \rho_l[1+\alpha_{2\theta}(\theta-\theta_l) \quad\text{---------------------------------}\quad 4$$

Where:

ρ_θ =The resistivity at any temperature e,
$\alpha_{2\theta}$ = the temperature coefficient of resistance at a temperature of 20DC,
ρ_l = the resistivity at temperature θ_l.

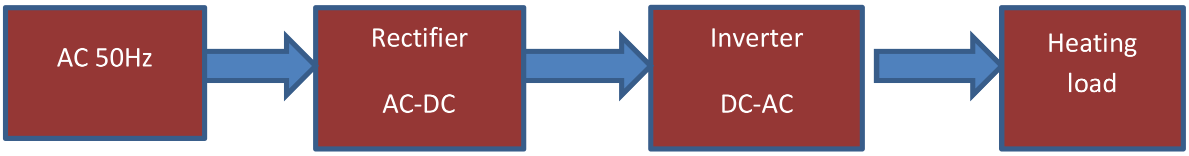
5.Hysteresis loss:-

For ferrous metals like iron and some types of steel, there is an additional heating mechanism that takes place at the same time as the eddy currents mentioned above. The intense alternating magnetic field inside the work coil repeatedly magnetises and de-magnetises the iron crystals. This rapid flipping of the magnetic domains causes considerable friction and heating inside the material. Heating due to this mechanism is known as Hysteresis loss, and is greatest for materials that have a large area inside their B-H curve. This can be a large contributing factor to the heat generated during induction heating, but only takes place inside ferrous materials. For this reason ferrous materials are mostly used for heating through induction than non-ferrous materials.

So, Induction heating depends on the above mentioned factors and how they get affected is also shown in their expressions.

Power source:-

Induction heating power supplies are frequency changers that convert utility line frequency (50Hz) power to the desired single-phase power at the frequency required by the induction heating processs. The rectifier portion of the power supply converts the single-phase line frequency input to DC, and the inverter portion changes the DC to single-phase high frequency (100kHz) AC. This is illustrated in the blocks below



Blocks showing different componenents of power supply

The load circuit:-

The induction-heating load forms part of a resonant tank circuit with a Q(varies from 3 to 18) . The power source is used to drive this tank circuit at its resonant frequency. The metal which is to be heated is situated inside a refractory crucible, which is placed inside the heating coil. When the coil is loaded a resulting shift in the resonant frequency of the tank circuit occurs. This shift in resonant frequency is directly related to the loading effect, which depends on the resistivity of the work-piece and the efficiency of coupling between the work-piece and the coil which had been discussed previously. This shift is compensated for by manually adjusting the driving frequency of the power source to the new load resonant frequency. When dealing with magnetic metals, frequency shifts also occurs during a heating cycle as in the ferromagnetic material (eg. steel), the relative permeability of that metal decreases with an increase in temperature, which causes a large shift in resonant frequency when the metal is heated through its Curie point. All of the factors mentioned above should be considered when heating and melting various metals by induction.

A problem thus exists when different metals are placed in the heating coil, because it would require the operator of the induction furnace to manually tune the system for maximum power and efficiency throughout the process. This situation is undesirable, because human intervention is not always as accurate and reliable as automatic control. An example of this situation occurs when heating a high melting point metal such as platinum. This process requires continuous maximum power transfer at all times. Incorrect manual tuning of the driving frequency could result in the freezing of the precious metal at the instant of pouring, due to insufficient heating above the metals melting point. The system also becomes less complicated to use, once automatic frequency control is implemented. Now this frequency controlled circuit will automatically look for the resonance frequency all the time when work piece is heated and will supply the maximum power.

Choice of frequency:-

Frequency is a very important parameter in induction heating because it is the primary control over the depth of current penetration and therefore over the depth of heating. Frequency is also important in the design of induction heating power supplies because the power components must be rated to operate at the specified frequency. Due to reduced switching losses at elevated switching frequencies (up to1MHz),various power devices such as enhancement-mode power MOSFETs, thyristors, and IGBTs have become an important component in high frequency power sources for induction heating For effective induction heating, the frequency of the alternating magnetic field in the work-coil is of paramount importance and is given by:-

$$f_c = 6.45\rho/\mu d^2 \quad \text{-----------------------------------} \quad 5$$

Where:-

f_c =critical frequency
ρ =the electrical resistivity of the work-piece (uΩm)
d=the diameter of the work-piece (m)
μ=the permeability of the work-piece (Hm^{-1})

As defined from above equation, below the critical frequency ,loss of heating occurs due to field cancellation of the work piece.

Relation between power density (P)and penetration depth(δ) is inversely related and as penetration depth(δ) is also inversely related with frequency.so we have

P proportional to $f^{0.5}$

So for large transfer of power we want to have large frequency supply.

Loading effect:-

The placing of metal in the heating coil tends to change the frequency characteristic of the load circuit. As the work piece is heated its relative permeability decreases and this decreases the inductance of coil which leads to major shift in the resonance frequency of the tank circuit. And this facilitates the need for frequency control to ensure maximum power transfer. Table below shows the resonant frequencies of the same load circuit with different metals placed inside the coil.

Metal	Diameter(mm)	Mass(g)	Frequency(Khz)
Copper	12.5	27.8	195.5
Gold	10	20	160.4
Steel	12	18.5	126.1
Nickel	9	10.5	134.5
Lead	10	12	156.4
Brass	12	24.3	183.3

Table 2 showing work piece properties

The induction-heating load forms part of a parallel resonant circuit, which is continuously driven at its natural resonant frequency by the inverter.

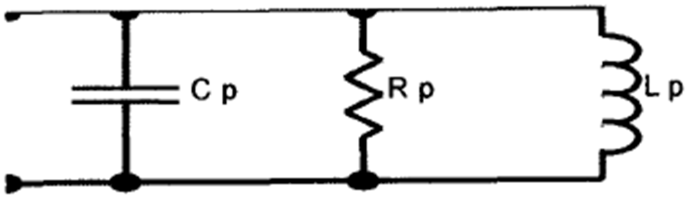


Figure 4.16 Equivalent circuit for induction heating load

The expression for the complex impedance of the parallel tuned circuit in above fig at any frequency (t) is given by the equation below:-

$$Z(f)= R_p/1+jQ_p(f/f_0-f_0/f) \quad \text{------------------------------------} \quad 6$$

where:-

R_p = Equivalent resistance of the tank circuit as seen by the source,
Q_p = Quality factor of the tank circuit and is given by $Qp = Rp / X_{Lp}$,
f_0 = Natural resonant frequency of the tank circuit.

The simulated load circuit parameters transformed to the terminals of the source are disscussed for three discrete conditions namely:

a.Unloaded heating coil:-

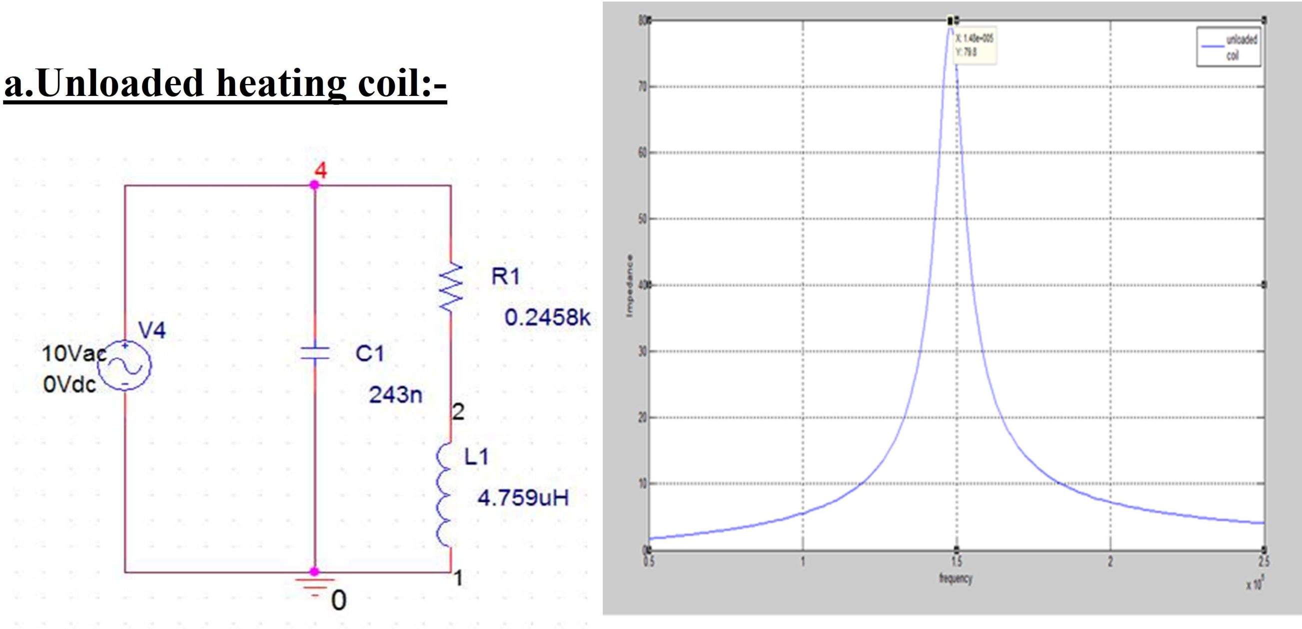
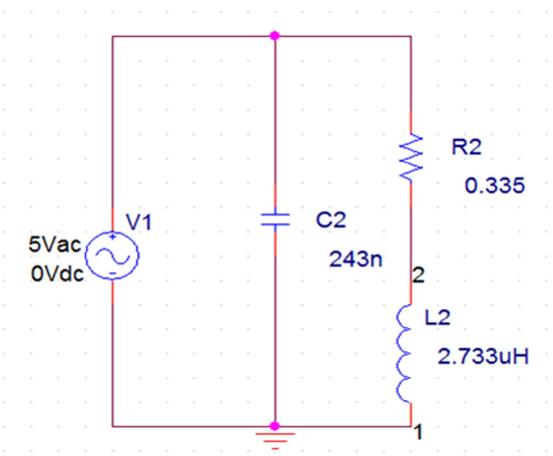


Figure 4.17 Load circuit and impedance curve for unloaded coil

The frequency response of the unloaded induction- heating coil is shoen in above figure. The resonant impedance is higher (79 ohm) for unloaded conditions, which improves the systems no load performance because of minimal current drawn from the supply (higher impedance at no-load). When the coil is loaded the load impedance is reduced and more current is drawn from the DC supply. The resonant frequency is approximately 148kHz with a Q of 18.

b.copper work piece:-

The frequency response of the loaded induction-heating coil is shown in the figure below



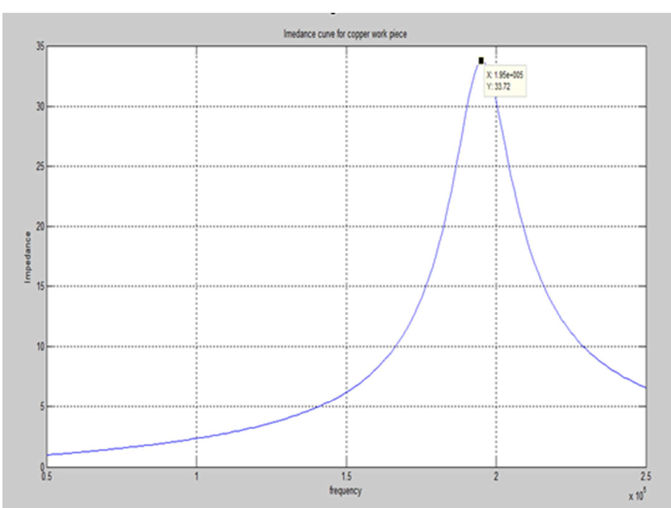


Figure 4.18 Load circuit and impedance curve for copper work piece

The copper piece has the parameters as shown in the above table 2. The resonant impedance is lower (33 ohm) for the loaded condition and more current is therefore drawn from the supply. The inductance of the coil (L2) is decreased due to the insertion of the copper work-piece resulting in an increase in the resonant frequency of the load circuit to approximately 195 kHz with a loaded Q of 10. The increase in resonant frequency results in a reduction in skin depth thereby increasing the equivalent resistance (R2) of the load circuit.

c. steel work piece:-

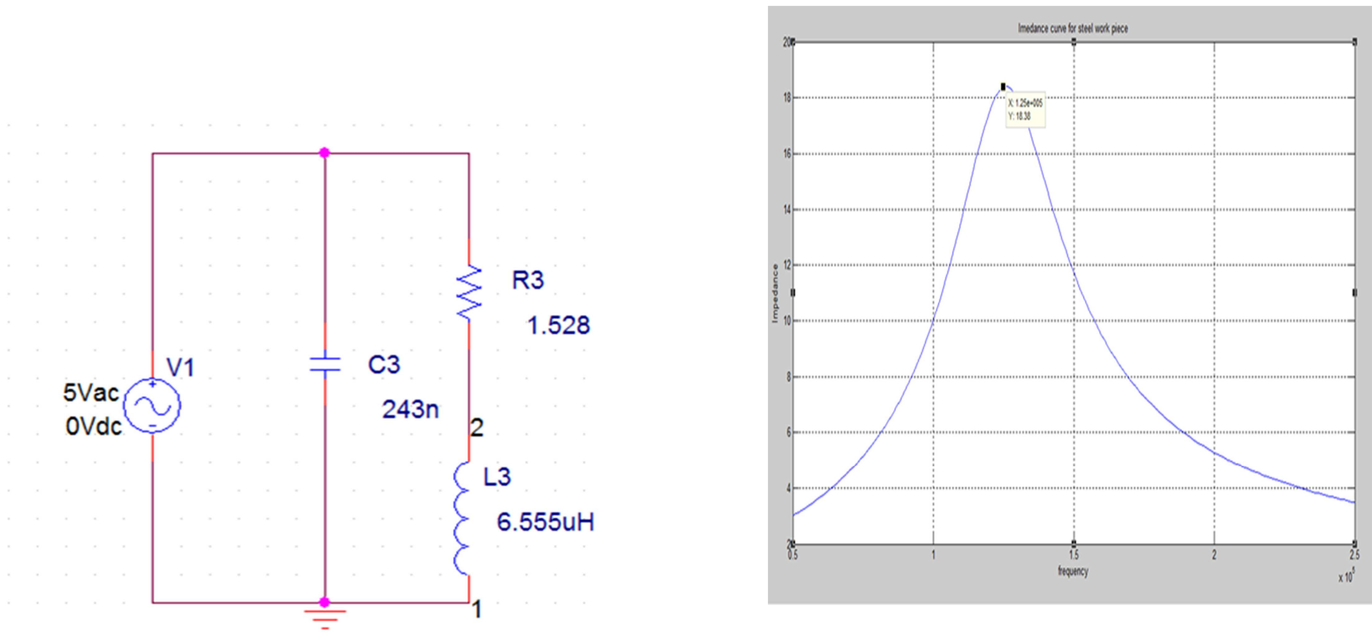


Figure 4.19 Load circuit and impedance curve for steel loaded coil

The frequency response of the loaded induction-heating coil is shown in the above fig.
The steel work-piece has the parameters as shown in table 2. The resonant impedance is the lowest (18 ohm) for this loaded condition and more current is drawn from the supply. The inductance of the coil is increased due to the insertion of the steel work-piece resulting in a decrease in the resonant frequency of the load circuit to approximately 126 kHz with a loaded Q of3.5.

The Q acts as an impedance transformer in a parallel resonant circuit. The lowering of the circuit Q as a result of inserting a steel work-piece, results in the reduction of the load circuit impedance while the steel work-piece is a better conductor of the magnetic flux in the coil than air is which tends to increase the inductance of the coil (L3) as can be seen in above figure. The equivalent resistance of the work-piece is also increased (R3) hence the power loss in th work-piece increases. This relationship is given by above equation for a relative permeability of several hundred in steel at room temperature.

Matlab Program and figure for finding resonance of load circuit for different work pieces:-

```
close all
clear all
clc
des='Y';
while (des=='Y')
C=input('value of capacitor');
R=input('value of resistor');
L=input('value of inductor:-');
S=input('supply voltage:-')
w=(2*pi*60*10^3):(2*pi*10^3):(2*pi*250*10^3);
l = length(w)
res=(1/(2*pi*L)*sqrt((L/C)-R^2))
for i=1:1:l
    a=1/(w(1,i)*C);
    b=L/(C*R);
    c=(w(1,i)*L)/R;
    d=1-(1/((w(1,i)^2)*(L*C)));
    Z1(1,i)=sqrt(a*a+b*b);
    Z2(1,i)=sqrt(1+((d*c)*(d*c)));
    Z(1,i)=Z1/Z2;
    Z
end
xlabel('frequency')
ylabel('impedance')
grid on
plot((w/2*pi),Z)
hold on
des=input('Do u want to proceed? Y orN');
end
```

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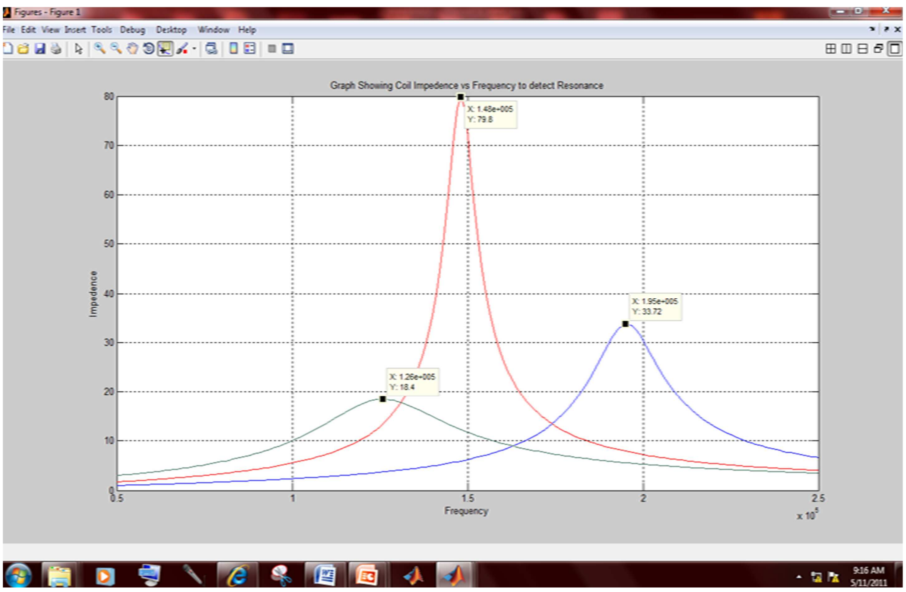


Figure 4.20 Matlab program and simulation curve for different load

Entry of PLC:-

Now from above explanation it could be said that due to work piece our supplied frequency shifted from the resonance which we don't desire since at resonance we have maximum power transfer from supply. So for automatic control of frequency we use PLC while earlier this function was done by the PLL circuits. However these circuits are complicated, difficult to calibrate, and sensitive to noise. Therefore, researchers thought of taking help of PLC.

Here we actually don't measure voltage and current from the working coil. Instead we apply a simple approach to identify the circuit deviation from the resonance. In parallel resonance circuits ,at resonance inductor current (I_L)and capacitor current(I_C)are equal but when operating frequency is below the resonance frequency ,I_L is larger than I_C while reverse happens when operating frequency is above the resonance frequency

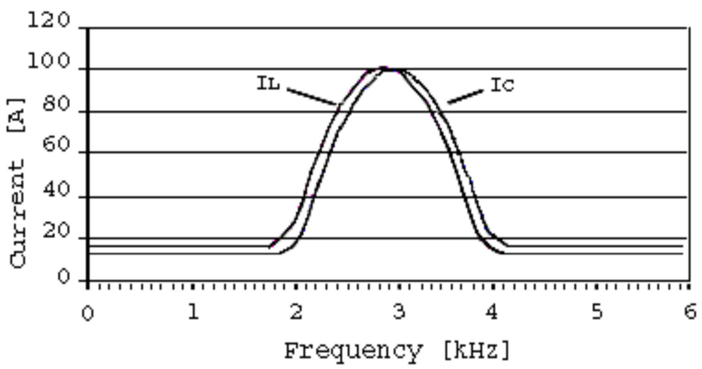
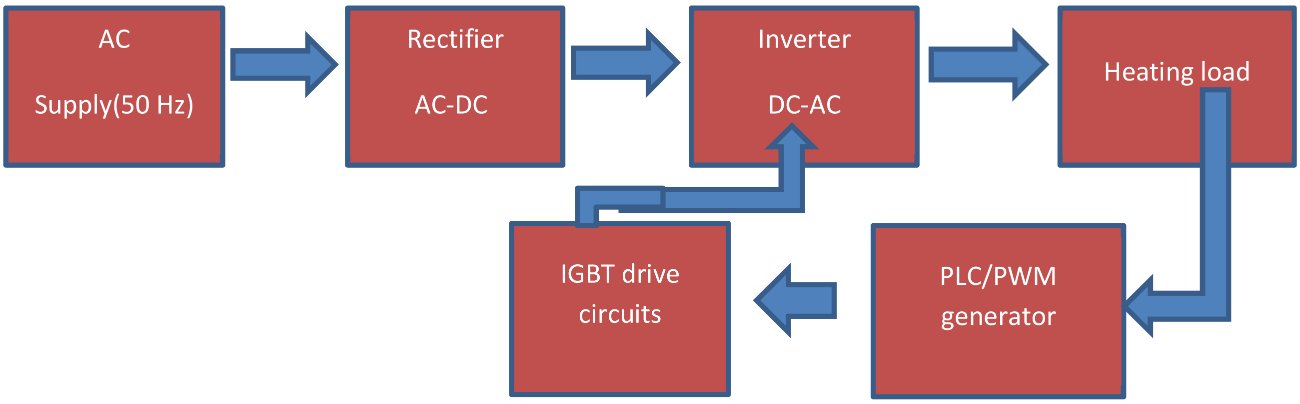


Figure 4.21 Resonance curve for parallel circuit

In the control circuit we have PI controllers. Current samples received from the inductor and capacitor are separately converted to voltage and filtered. Each signal is then passed through a PI regulator. PI regulator outputs are applied to a differential amplifier. While the bandwidth of the amplifier can be adjusted accordingly. And finally the output of the differential amplifier is used to control the PLC drive.

PLC program:-

Siemens's S7-200/CPU model PLC has been chosen for the hardware implementation. This PLC has 14 inputs,10 outputs and, PWM and PTO generators. These generators cab be directed to Q0.1 and Q0.2 outputs. It also has the input-output capability to perform certain functions such as placing and removing the work piece, temperature ,pressure and position control. The written program has two main components. The first part generates the necessary pulses for the inverter, while the second one is responsible for the control of the induction furnace.



Blocks showing different power components along with PLC controller

The availability of solid state power sources enables us to make use of PLC more efficiently. It has enabled conversion efficiencies of up to 93 % due to low switching losses and good high frequency coupling. Solid state power sources used to drive induction-heating loads are usually very efficient, provided that the load is driven at its natural resonant frequency. This allows zero voltage (ZYS) and or zero current (ZCS) switching of the converter, resulting in reduced power losses in the semiconductor switches.

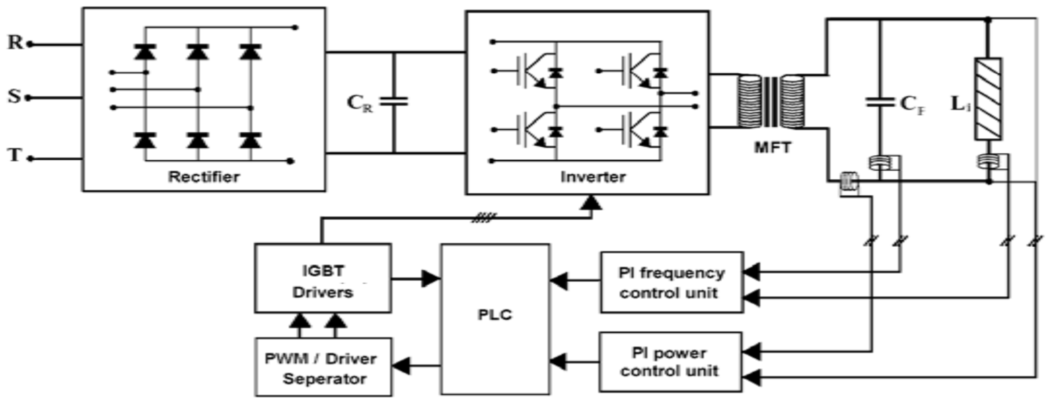
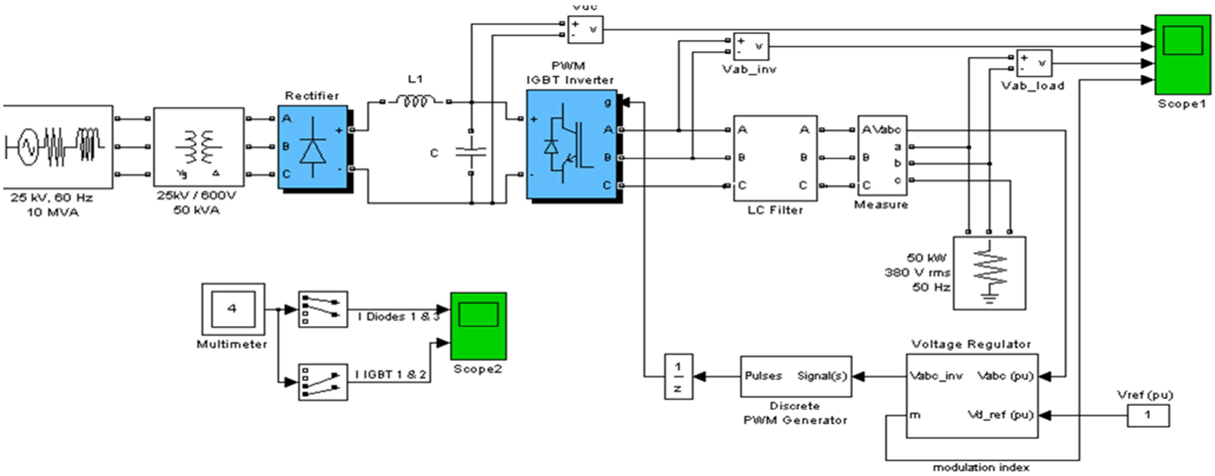


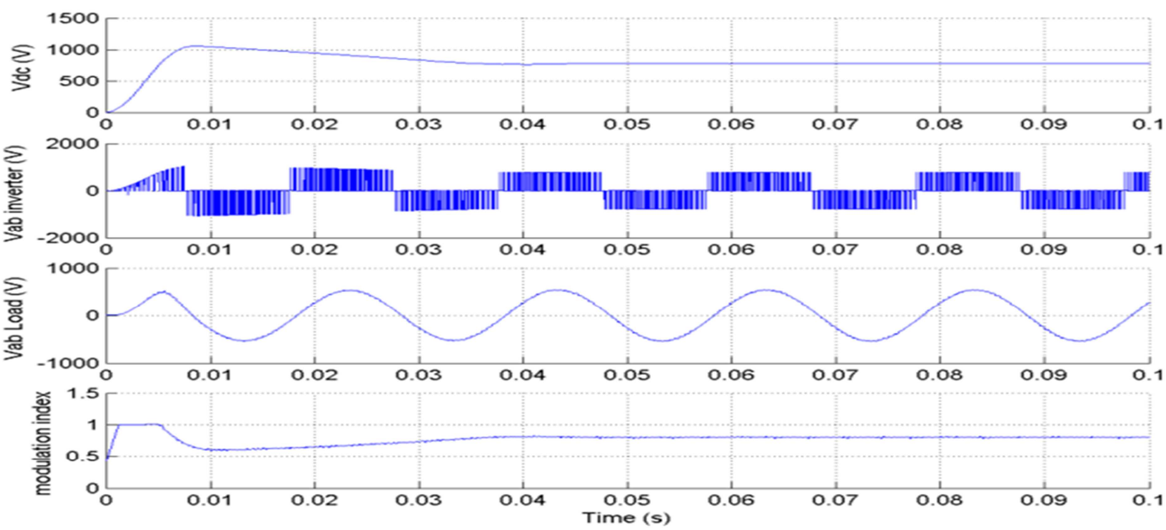
Figure 4.22 Block diagram of induction steel heating furnace

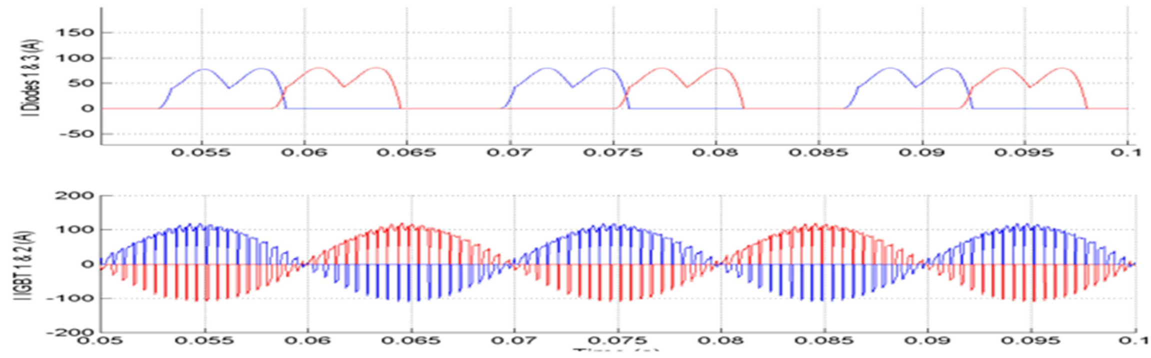
Matlab /Simulink:-

The help of this tool was taken to find out the gate driving pulses for inverter and to find out the output voltage from the inverter .The reference signal is provided accordingly by the PLC circuit.

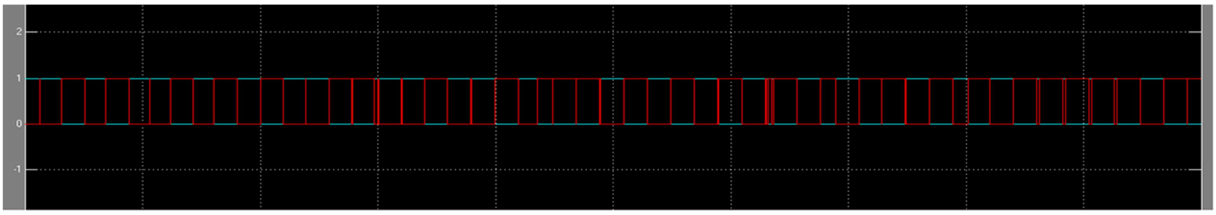


Simulation results:-





I Diodes 1 & 3 (A)
150
100
50
0
-50
0.055
0.06
0.065
0.07
0.075
0.08
0.085
0.09
0.095
0.1
I IGBT 1 & 2 (A)
200
100
0
-100
-200
0.05
0.055
0.06
0.065
0.07
0.075
0.08
0.085
0.09
0.095
0.1



2
1
0
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Chapter 5

Conclusion

5. Conclusion:-

So the implementation of the PLC was carried out effectively for various industrial applications.It proves to be one of the important controller in industries for its simplicity and robustness and is used all over the world.For any control design approach understandings of the desired control system and how to use the ladder diagram to translate the machine sequence of operation are the most imporatant parts,because it has direct effect on the system performance. PLC's are very good for controlling outputs based on the inputs.They are amazingly robust and are able to withstand all sorts of difficult conditions such as extreme temperature or dust in the air.They even last for a very long period.They don't have contacts that wear out,like relays do.they also can switch fairly quick without much heating in direct contrast to relays.For any application we need not to change the whole structure only different program has to be embedded as like any other programmable devices. Compared to relays PLCs are almost always a better choice.

On the downside it could be observed that PLCs are not very good at handling large amount of data,or complex data. Computers are better for those tasks.PLCs are also not very good with databases or displaying data. Lack of standardization is also one of the major disadvantage of the PLC. This causes much confusion if the PLC used for an application is replaced by one from a different manufacturer, or if a PLC programmer is replaced by a person with a different understanding of PLC programming.

The applications which we did can even better be performed with some further improvements. In the bottle filling system ,only one limit switch was used to detect the position of the bottle. This process has become quite obsolete, instead IR sensor can be used.It will be better if we add more sensors in this system like a flow sensor to detect water flow or use level sensor to detect water level. Thus, the system will be more sensitive as there will bemore sensing points
Besides using PLC as controller, the other controller can be used in this future work is likeMicrocontroller. However, many factors must be considered like cost, practically and others.

Talking about the control of dc motor, it is important for the machine designer to be very familiar with various methods of controlling ac and dc motor. These range from the simple motor starter to the sophisticated pulse width modulated (PWM) dc motor controls . The pulse width modulator (PWM) system is capable of efficiently controlling the speed of a dc motor by controlling the average armature voltage of the motor.

For induction heating PLC equipped with solid state devices provided much control features to the process. Here no special matched filtering circuitry was needed to filter the signals to be phase locked. Also the current measurement was not needed for the approximation of the load current phase displacement.
One extra feature that can be added in the induction heating process is the temperature control. The temperature of the work piece needs to be monitored throughout the heating cycle to ensure that the work-piece temperature never exceeds the maximum temperature of the crucible.

The implementation of temperature control would be advantageous because it would extend the applications of the induction furnace. The system could then be used for special laboratory applications, which require precision heating of small quantities of metal. Examples of applications include silicon crystal growing, tungsten refining and special high-purity alloying with metals like titanium, ruthenium and platinum.

One important point that needs to be included is the implementation of Overload and short circuit protection in the system. Also investigations need to be conducted to determine what kind of harmonics the system could be injecting back into the line frequency power source. If the need arises a front-end power factor correction system could be implemented which would incorporate a DC-DC converter in place of the controlled rectifier.

Thus the whole study and implementation dealing with the study of the PLC was satisfactorily carried out.

Chapter 6

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